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INVESTIGATION OF MECHANICAL PROPERTIES OF BIDIRECTIONAL CARBON / GLASS REINFORCED EPOXY HYBRID COMPOSITES

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ABSTRACT

Now a day the demand for composite products is increasing, ranging from utilitarian underground pipes to high-performance aircraft. Carbon fiber is significantly more expensive than glass fiber, so it is mainly used for high-performance applications where weight saving requirements is critical such as in aircrafts, electric and sports cars, and wind turbine blades, which are getting increasingly longer. Glass fiber has been used in thousands of applications and has thus demonstrated an excellent track history. Glass fibers alone have very less Young's modulus, shear modulus, flexural strength and because of this disadvantage this material is not recommended for many works in aircrafts. This draws attention on the development of hybrid composites in which glass and carbon fibers are laid up in different orientations. Hybrid composites are expected to have good mechanical properties like pure carbon composites and will replace carbon composites in many applications because of their low cost compared to carbon composites. In this paper, we fabricated pure carbon composite plate having orientations 45^0, 90^0 and hybrid composite plate (carbon and glass fiber) having orientations 45^0, 90^0. Specimens are cut from these plates to test tensile, flexural and shear strengths.

KEYWORDS: Bi-directional Carbon Fiber, Bi-Directional Glass Fiber, Hybrid Composite, Tensile Strength, Flexural Strength & Shear Strength

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Original Article

1. INTRODUCTION

Hull D & Clyne T W, Hybrid composites are more advanced composites as compared to conventional FRP composites. Hybrids can have more than one reinforcing phase and a single matrix phase or single reinforcing phase with multiple matrix phases or multiple reinforcing and multiple matrix phases. They have better flexibility as compared to other fiber reinforced composites. Normally it contains a high modulus fiber with low modulus fiber. The high-modulus fiber provides the stiffness and load bearing qualities, whereas the low-modulus fiber makes the composite more damage tolerant and keeps the material cost low. The mechanical properties of a hybrid composite can be varied by changing the volume ratio and stacking sequence of different plies. Most of the research and development is concerned with the replacement of the aluminum alloy; steel aircraft body to the FRP body so as to decrease the weight of it and eventually the cargo capacity will increase further. Engineers who blueprint aero-planes are seriously concerned with weight since reducing a craft weight reduces the amount of fuel it needs and also increases the speed. Also, specific strength and dimensional stability hold an important property while building aeroplanes as they need a very high strength material at lowest possible weight and the latter states that composite materials retain their shape and size when they are hot or cold, dry or wet. The advancement of FRP composites in

aerospace has resulted in the combination of two or more different fibers such as glass and carbon into a structure to improve its mechanical performance at little cost.

P. M. Bhagwat, M. Ramachandran, Pramod Raichurkar tested unidirectional carbon-glass hybrid composite to developed a setup on the UTM to conduct tests like a tensile and compressive test. They found Young's modulus of the specimens, both in tensile and compressive. They compared the results with the glass fiber reinforced plastic (GFRP) material. The hybrid composites were having excellent mechanical properties. Therefore, this hybrid fiber-reinforced composites can be used as a replacement of glass FRP material where there is a need of good mechanical properties.

Elias Randjbaran, Rizal Zahari, Nawal Aswan Abdul Jalil, and Dayang Laila Abang Abdul Majid, investigated the effects of stacking sequence layers of hybrid composite materials on ballistic energy absorption by running the ballistic test at the high-velocity ballistic impact conditions. The velocity and absorbed energy were accordingly calculated as well. The specimens were fabricated from Kevlar, carbon, and glass woven fabrics and resin and were experimentally investigated under impact conditions. All the specimens possessed equal mass, shape, and density; nevertheless, the layers were ordered in different stacking sequence. After running the ballistic test at the same conditions, the final velocities of the cylindrical AISI 4340 Steel pellet showed how much energy was absorbed by the samples. The energy absorption of each sample through the ballistic impact was calculated; accordingly, the proper ballistic impact resistance materials could be found by conducting the test. This paper can be further studied in order to characterize the material properties for the different layers. The results show, first, that Hybrid 2 has the superlative energy absorption of 95.17 J. Second, it can be concluded that stacking the first layer with glass fiber is better than to use the Kevlar fiber, according to Hybrid 2 and Hybrid 4 impact specimens with ballistic impact energy absorption of 95.17 J and 95.15 J, respectively. Moreover, the results indicated that using the combination of carbon and glass is more efficient to in the central layers. Third, in accordance with Hybrid 1 with ballistic impact energy absorption of 94.36 J, using the carbon fiber is not recommended at the last layer.

R. H. Patel, V. R. Sevkani, B. R. Patel and V. B. Patel did work on hybrid composites in which glass/carbon fiber reinforcement have been used with a matrix triglycidyl ether of tris(m-hydroxy phenyl) phosphate epoxy resin using amine curing agent. They tested physical and mechanical properties of the glass, carbon and glass/carbon fiber reinforced polymeric systems. They found that 6CF and 4GF show highest flexural strength compare to the other systems.

2. MATERIALS

2.1. Carbon Fiber

The primary element of CFRP is a carbon filament: this is produced from a precursor polymer such as poly acrylo nitrile (PAN), rayon, or petroleum pitch. For synthetic polymers such as PAN or rayon, the precursor is first spun into filament yarns, using chemical and mechanical processes to initially align the polymer chains in a way to enhance the final physical properties of the completed carbon fiber. Precursor compositions and mechanical processes used during spinning filament yarns may vary among manufacturers. After drawing or spinning, the polymer filament yarns are then heated to drive off non-carbon atoms (carbonization), producing the final carbon fiber. The carbon fibers filament yarns may be further treated to improve handling qualities, then wound on to bobbins. From the elementary fiber, a bidirectional woven sheet can be created, i.e. a twill with a 2/2 weave. The process by which most CFRPs are made varies, depending on the piece being created, the finish (outside gloss) required, and how many of this particular piece is going to be produced. In addition, the choice of the matrix can have a profound effect on the properties of the finished composite. The carbon fiber used in this paper is as shown in Figure 2.1.

2.2. Glass Fiber

There are two main types of glass fiber manufacture and two main types of glass fiber product. First, fiber is made either from a direct melt process or a marble remelt process. Both start with the raw materials in solid form. The materials are mixed together and melted in a furnace. Then, for the marble process, the molten material is sheared and rolled into marbles which are cooled and packaged. The marbles are taken to the fiber manufacturing facility where they are inserted into a can and re-melted. The molten glass is extruded to the bushing to be formed into a fiber. In the direct melt process, the molten glass in the furnace goes directly to the bushing for formation. The glass fiber used in this paper is as shown in Figure 2.1.

2.3. Matrix

Epoxy resin (EP-306 grade epoxy resin & EH-758 grade hardener) as shown in Figure 2.1 is selected as a matrix. Epoxy resins are more expensive than polyester, but have superior mechanical properties, higher dynamic strength and fatigue resistance. The epoxy resin laminate has low water absorption with high tensile and shear strengths. Epoxy resins are the ultimate choice of the FRP fan blades and are more advantageous in hollow construction.

A 250 ml epoxy is taken separately and then mixed with 25 ml of hardener. The hardener is high viscous liquid material, mixed with resin in suitable proportion during the process of preparation of composites which helps in the solidification of the wet, smooth composite. It is used to harden the smooth composite, hence it is called as the hardener. In this project, an EH-758 grade of hardener is used to mix with epoxy resin in 1:10 proportions in the process of manufacturing of composite.

Figure 2.1: Carbon Fiber, Glass Fiber, Epoxy Resin and Epoxy Hardener (Left to Right)

3. COMPOSITE PREPARATION

The steps involved in the fabrication of CFRP/CGFRP-Epoxy composite laminates by hand layup process is described as follows:

- Each fiber mat is cut to a length and width of 250mm *100 mm according to required orientation (90^0 or 45^0)

In this work 4 composite plate of thickness, nearly 6.9 mm is prepared. They are C1, C2, C3, and C4.

C1: Pure Carbon 90^0 Lay-up

For C1 specimen total 11 layers of bi-directional carbon fibers (0^0-90^0) used among them, 2 layers for top and bottom sheets each of 0.3mm thickness and 9 for intermediate layers each 0.7mm the thickness. Figure 3.1 shows a layup sequence in terms of thickness of fibers: (C+9*0.7C+0.3C)

C2: Pure Carbon 45^0 Lay-up

For C2 specimen total 11 layers of bi-directional carbon fibers (45^0-45^0) used among them, 2 layers for top and bottom sheets each of 0.3mm thickness and 9 for intermediate layers each 0.7mm the thickness. Lay-up sequence in terms of thickness of fibers: (0.3C+0.7C+0.3C)

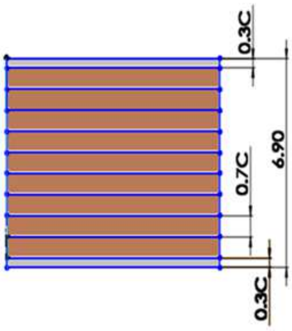

Figure 3.1: Lay-up Sequence of C1 Plate

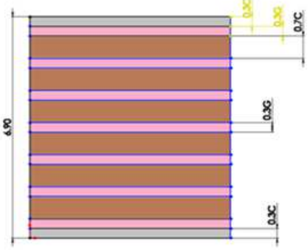

Figure 3.2: Lay-up Sequence of C3 Plate

C3: Hybrid Carbon/Glass 90^0 Lay-up

For C3 specimen total 15 layers of alternate bi-directional layers (0^0-90^0) of carbon and glass fibers are used. Among them, 2 layers of carbon sheets for topmost and bottom most layers, each of 0.3mm thickness, 6 intermediate carbon layers, each of 0.7mm thickness and 7 intermediate glass layers each of 0.3mm thickness. Figure 3.2 shows lay-up sequence of C3 plate in terms of thickness of fibers: (0.3C+0.3G+0.7C+0.3G+0.7C +0.3G+0.7C +0.3G+0.7C +0.3G+0.7C +0.3G+0.7C +0.3G+0.3C).

C4: Hybrid Carbon/Glass 45^0 Lay-up

For C4 specimen total 15 layers of alternate bi-directional layers (45^0-45^0) of carbon and glass fibers are used. Among them, 2 layers of carbon sheets for topmost and bottommost layers, each of 0.3mm thickness, 6 intermediate carbon layers each of 0.7mm thickness and 7 intermediate glass layers each of 0.3mm thickness.

- A flat surface cardboard is chosen for lay-up of the fibers.
- Next a releasing agent is applied to the card bard. A releasing agent is generally used to prevent the sticking specimen to cardboard due to epoxy from the specimen and it also helps in easy removal of work part from the cardboard after curing process. The cardboard with releasing agent is shown in Figure 3.2, and then proceeds to the next step. In the present test we applied grease as a releasing agent.

Figure 3.3: Applying Releasing Agent on Card Board

- After applying releasing agent resin is applied to cardboard as shown in Figure 3.4.
- Then a carbon sheet is placed on the cardboard over which resin is applied is as shown in Figure 3.5.
- Next fiber layer of either carbon or glass (based on lay-up sequence C1, C2, C3 and C4) is placed over a carbon sheet as shown in figure 3.6. (For C3 plate), and then the resin is applied.
- The procedure is repeated till a thickness of 6.9mm reached. Every time after applying resin a cylindrical roller is rolled over the lamina to remove air bubbles.
- Finally, on the top carbon sheet is placed.
- The 4 composite plates C1, C2, C3 and C4 are allowed to cure in atmospheric air for 7 days as shown in Figure 3.7.
- Take a tool and lift the specimen from all the corners, then specimen is removed from the cardboard and mark the required dimension of standard specimens tensile, flexural and shear on each composite plate and cut accordingly with blade and file the edges neatly.

Figure 3.6: Applying Resin on Card Board

Figure 3.7: Applying Resin over Carbon Fiber

Figure 3.8: Applying Resin on Glass Fiber (plate C3)

Figure 3.9: Curing of C3, C4 Plates

3.1. Preparation of Standard Specimens from Composite Plates

The plate is cut according to the international standard 1998-1962 which is standard for testing thermosetting synthetic resin. Specimens are cut as per to get specimens for testing tensile, flexure and shear properties.

3.1.1. Tension Test Specimen

As per IS standards tension testing specimen cut from plates C1, C2, C3, and C4. The figure 3.10 shows tension testing specimen cut from plate C3. Its dimensions are 210mm length, 14mm width and 6.9 mm thickness

Figure 3.10: Tension Testing Specimen Cut from C3 Plate

3.1.2. Cross Bending Test Specimen

As per the dimensions are shown in Figure 3.12 flexure testing specimen cut from plates C1, C2, C3 and C4. The figure 3.12 shows tension testing specimen cut from plate C3. Its dimensions are 100 mm length, 18.23 mm width and 6.9 mm thickness.

Figure 3.11: Flexure Testing Specimen Cut from C3 Plate

3.1.3. Shear Test Specimen

As per the dimensions are shown in Figure 3.12 shear testing specimen cut from plates C1, C2, C3 and C4. The figure 3.12 shows tension testing specimen cut from plate C3. Its dimensions are 70 mm length, 5.88 mm width and 6.9 mm thickness.

Figure 3.12: Shear Testing Specimen Cut from C3 Plate

4. RESULTS & DISCUSSIONS

4.1. Comparison of Tensile Strength

In this test, the tensile behavior of reinforced polymer composites in a different orientation of lay-up sequence is found. The tensile test was carried out on MCS 60 UTE-60N as per the IS standards. The four specimens were subjected to tensile load and the maximum load values were reported. The tensile strengths of specimens C1, C2, C3 and C4are observed in Figure 4.1. It is found that C3 specimen has the highest tensile strength compared to remaining specimens and is found as 453.14 MPa. But C4 specimen has less tensile strength than pure carbon specimens.

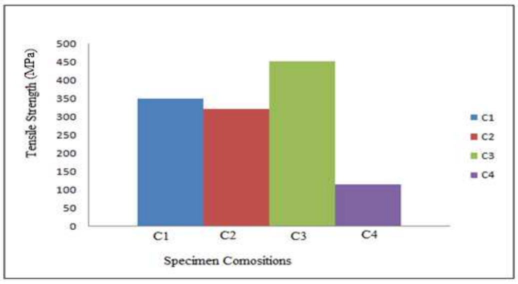

Figure 4.1: Comparison of Tensile Strength

4.2. Comparison of Flexural Strength

In this test, the flexural behavior of reinforced polymer composites in the different orientation of lay-up sequence is found. The flexural test was carried out on MCS 60 UTE-60N as per the IS standards. The four specimens were subjected to transverse load and the maximum load values were reported. The flexural strengths of specimens C1, C2, C3 and C4are observed in Figure 4.2. It is found that C1 specimen has highest flexural strength compared to remaining specimens and is found as 644 MPa. It is found that the hybrid composites have less flexural strength compared to pure carbon specimens.

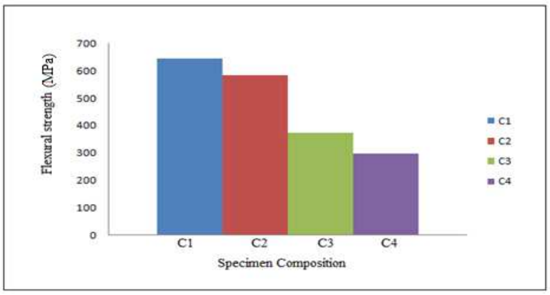

Figure 4.2: Comparison of Flexural Strength

4.3. Comparison of Shear Strength

In this test, the shear behavior of reinforced polymer composites in different orientation of lay-up sequence is found. The shear test was carried out on MCS 60 UTE-60N as per the IS standards. The four specimens were subjected to shear load and the maximum load values were reported. The shear strengths of specimens C1, C2, C3, and C4are observed in Figure 4.3. It is found that C4 specimen has highest shear strength compared to remaining specimens and is found as 170.54MPa. It is also found that pure carbon specimens also have good shear strengths comparable to C3 specimen.

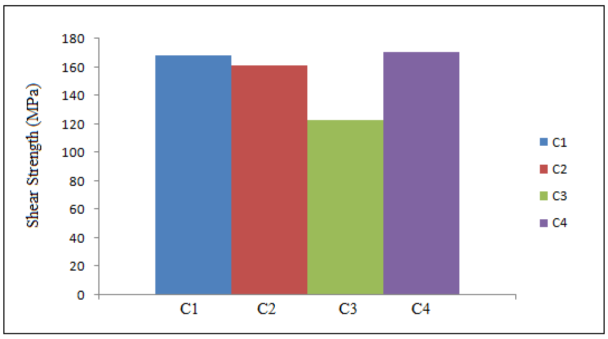

Figure 4.3: Comparison of Shear Strength

5. CONCLUSIONS

It is found that hybrid composite having 90^0 orientations (C3) has the highest tensile strength among all the specimens. The hybrid composite having 45^0 orientations (C4) havehighest shear strength among all the specimens. But the flexural strength of the hybrid composite is less compared to pure carbon specimens. Based on the result it is concluded that hybrid composites made of carbon and glass fibers is a promising solution to reduce cost and we can use them in place of pure carbon composites.

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